High Accuracy Thermal Expansion Measurement at Cryogenic Temperatures

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Engineering Research Center Birmingham, AL

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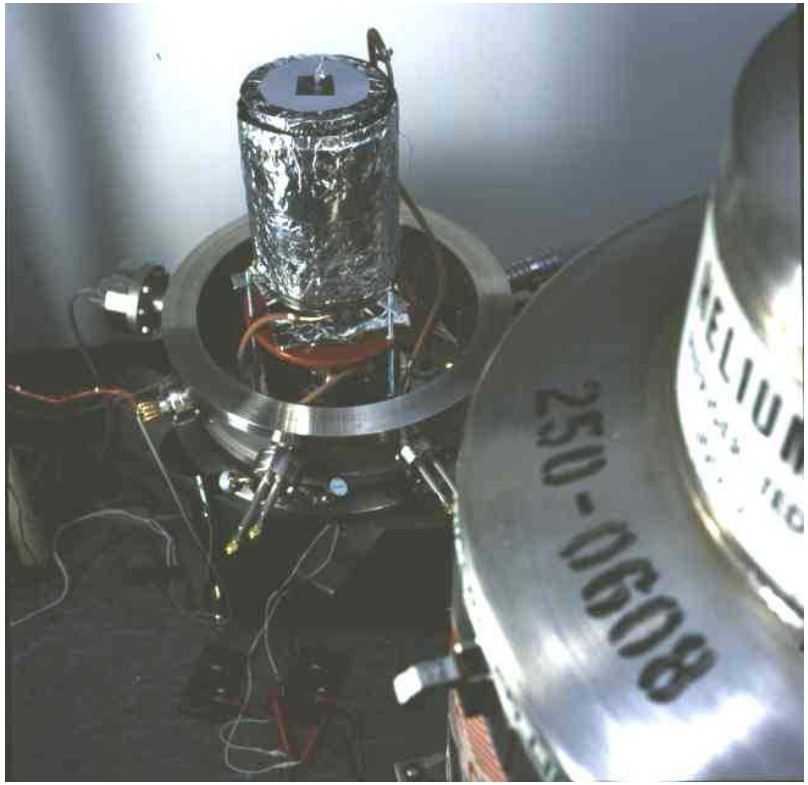
Southern Research provides a wide range of capabilities based on decades of composite testing in extreme environments.



- Thermal Properties
  - Coupon Thermal Expansion
  - Ring (Hoop) TE
  - Thermal Conductivity (CRA)
  - Heat Capacity
- Mechanical Properties
  - Tension
  - Compression
  - Shear (Torsion)
  - Flexure
- Nondestructive Testing
  - Electrical Resistivity
  - Ultrasonic Characterization (Young's Modulus, Shear Modulus)

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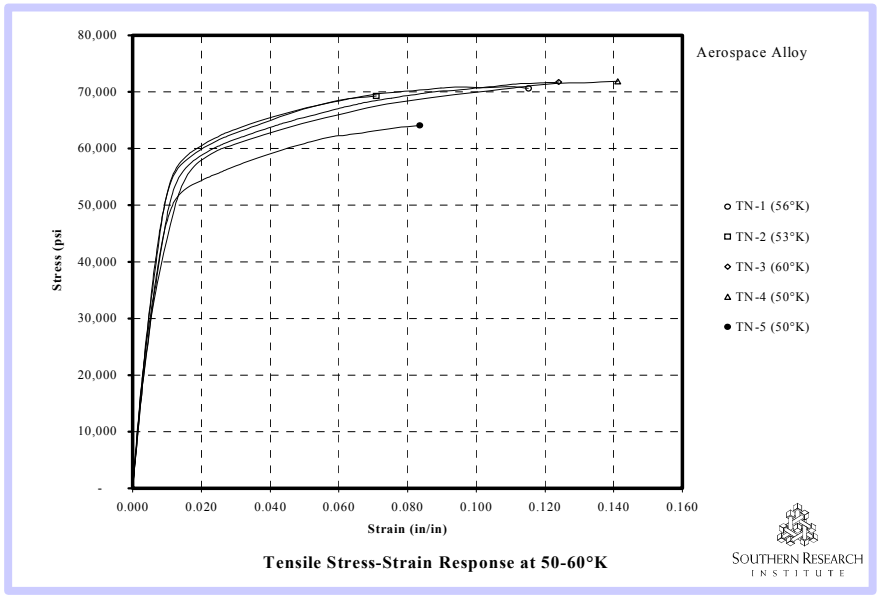
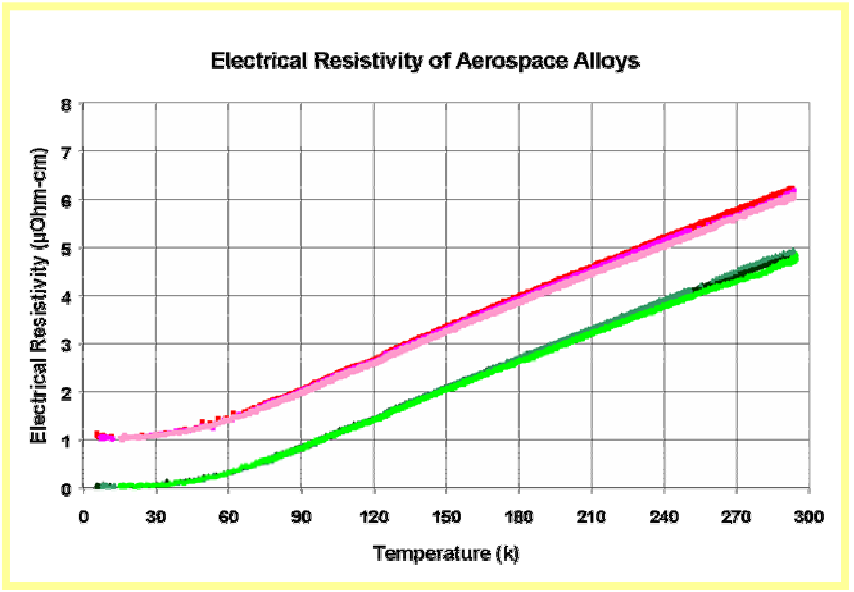
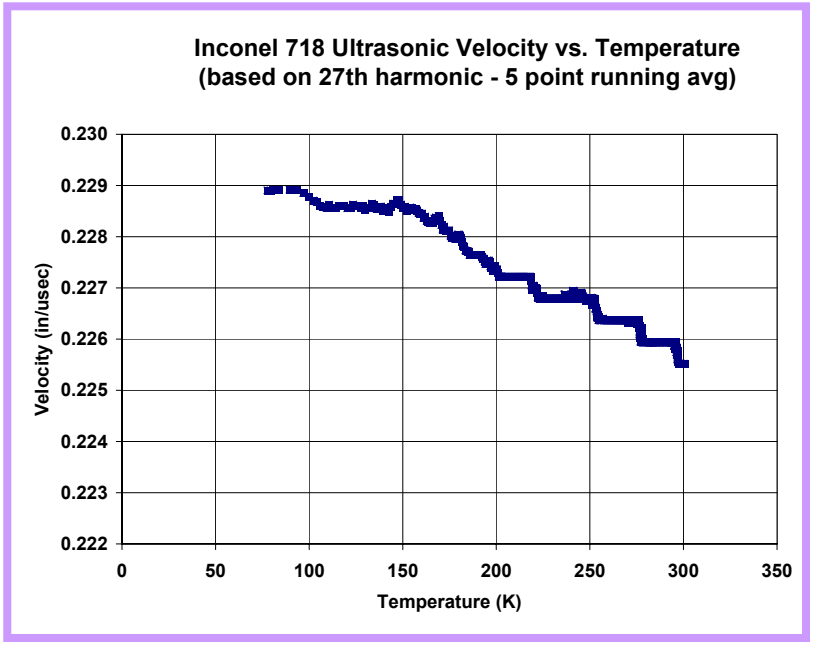
Data from Various Material Properties







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High Accuracy Thermal Expansion Testing

- Interferometer Based
  - Multiple pass, differential interferometers (arrangement allows for self cancellation of large errors from abbe´ and optics thermal drift)
  - No back-out factors (no reference material, nothing measured except specimen)
  - Mirror targets are coplanar with ends of specimen
  - Temperature measured with diodes on specimen
- Minimal Specimen Requirements
  - 0.5” to 8” length
  - Ends parallel to 100 arc-seconds
  - Minimum 0.05 square-inch area ends
  - Avoid stay-out zone
- Temperature Range 15 K to 350 K
- CTE accuracy for 10 K delta is between 5 and 25 ppb depending on specimen (length, conductivity, etc.)

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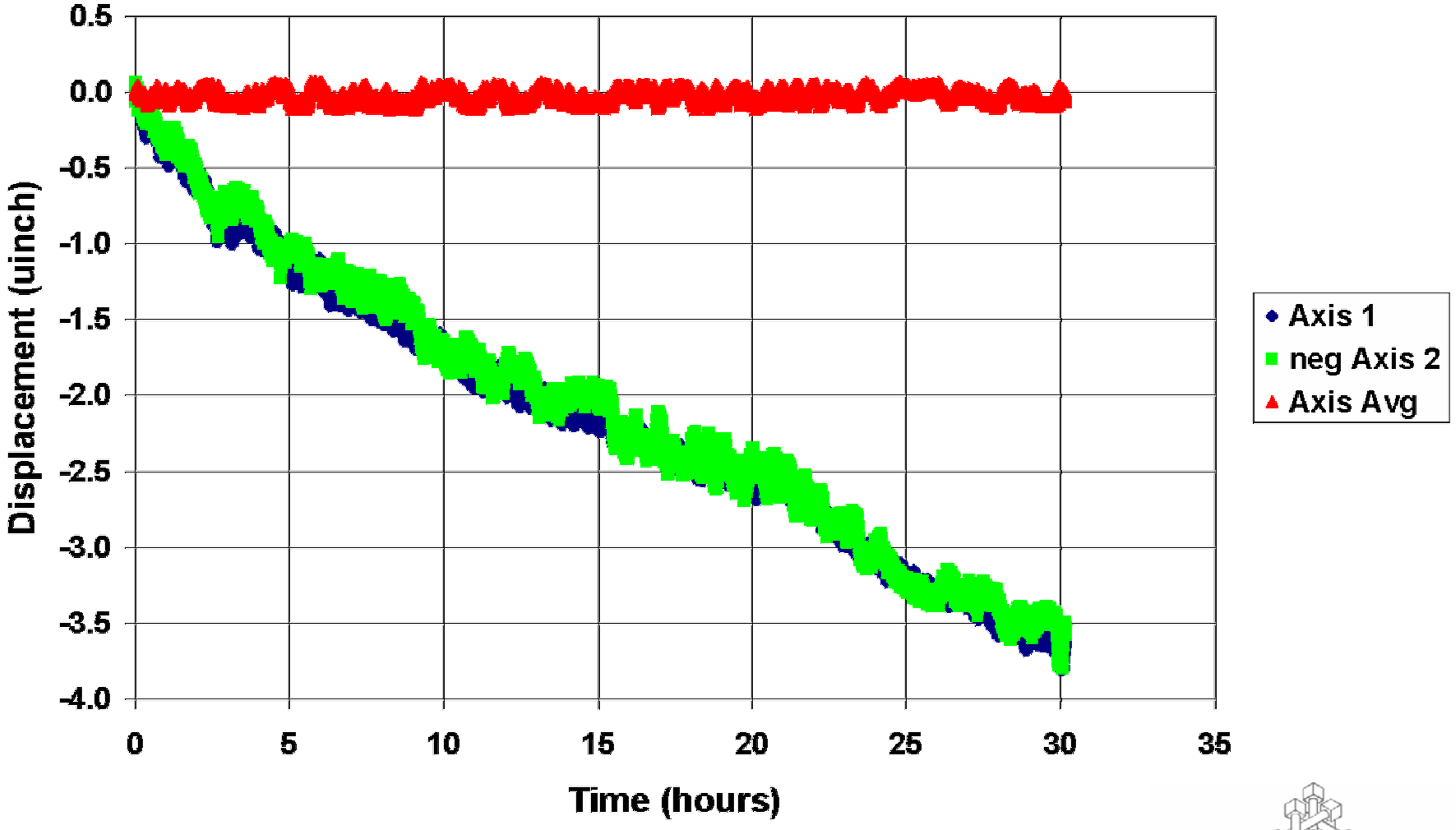
Interferometer Stability Over Time



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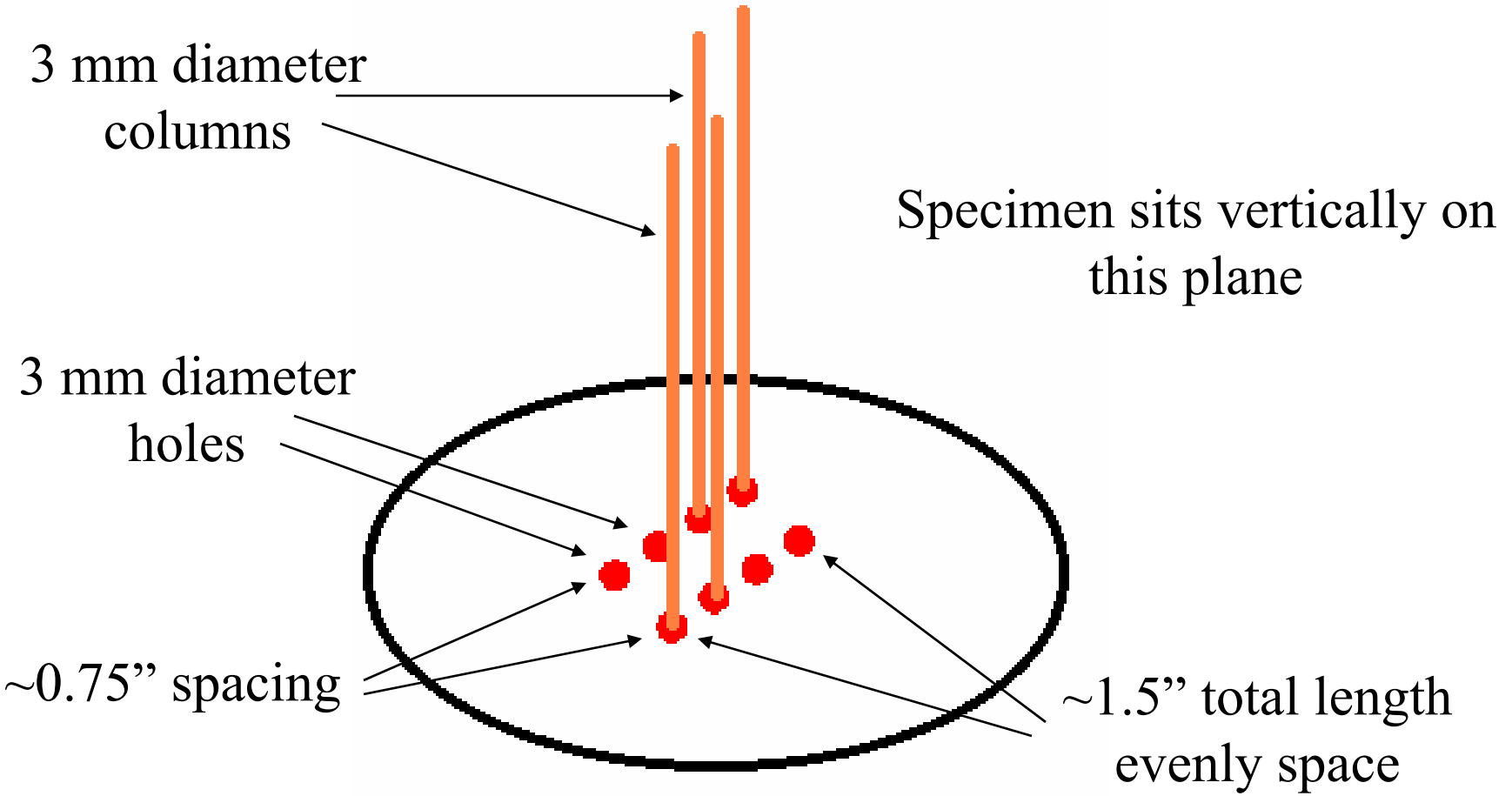
Definition of "Stay-Out" Zone



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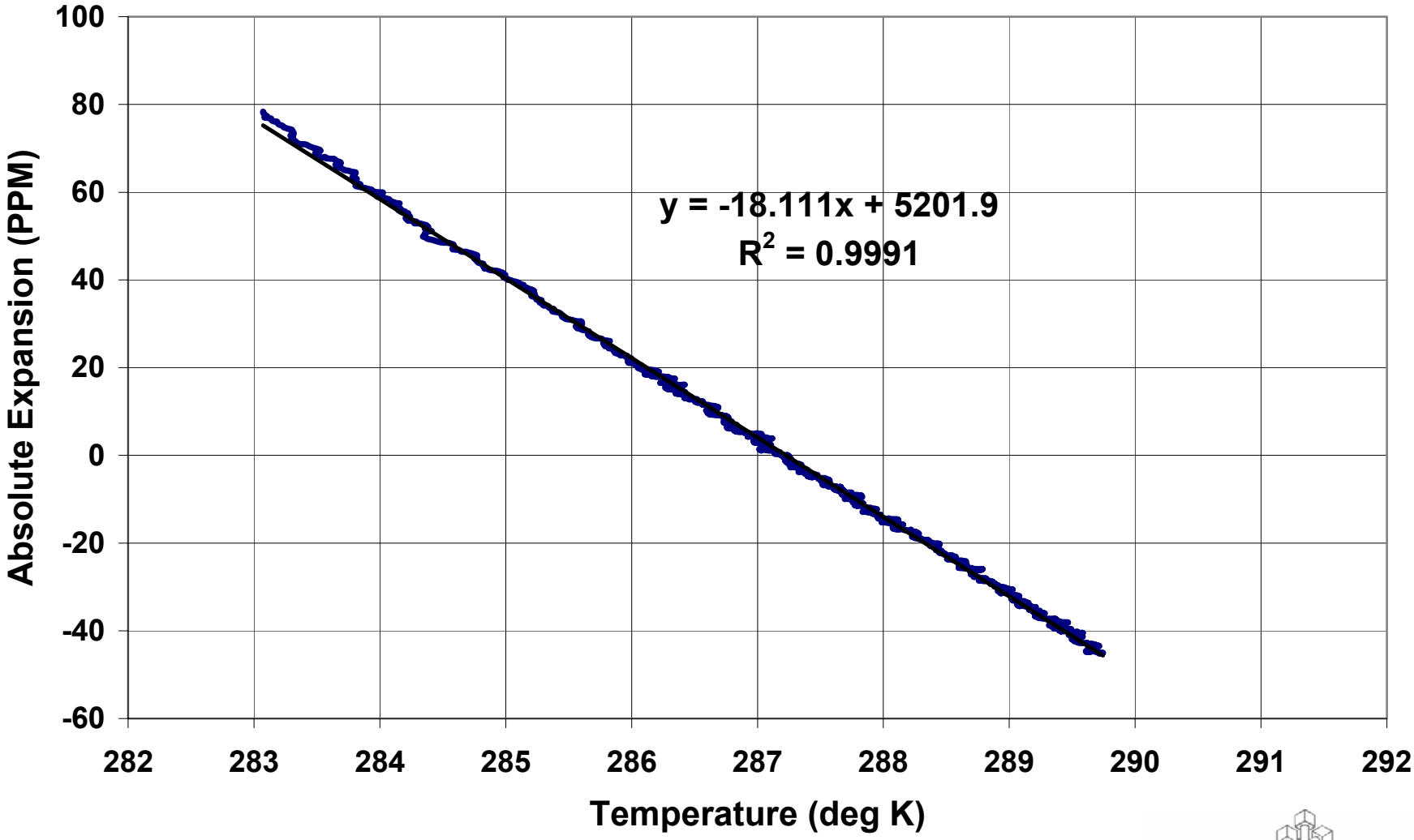
1" Honeycomb Core Thermal Expansion



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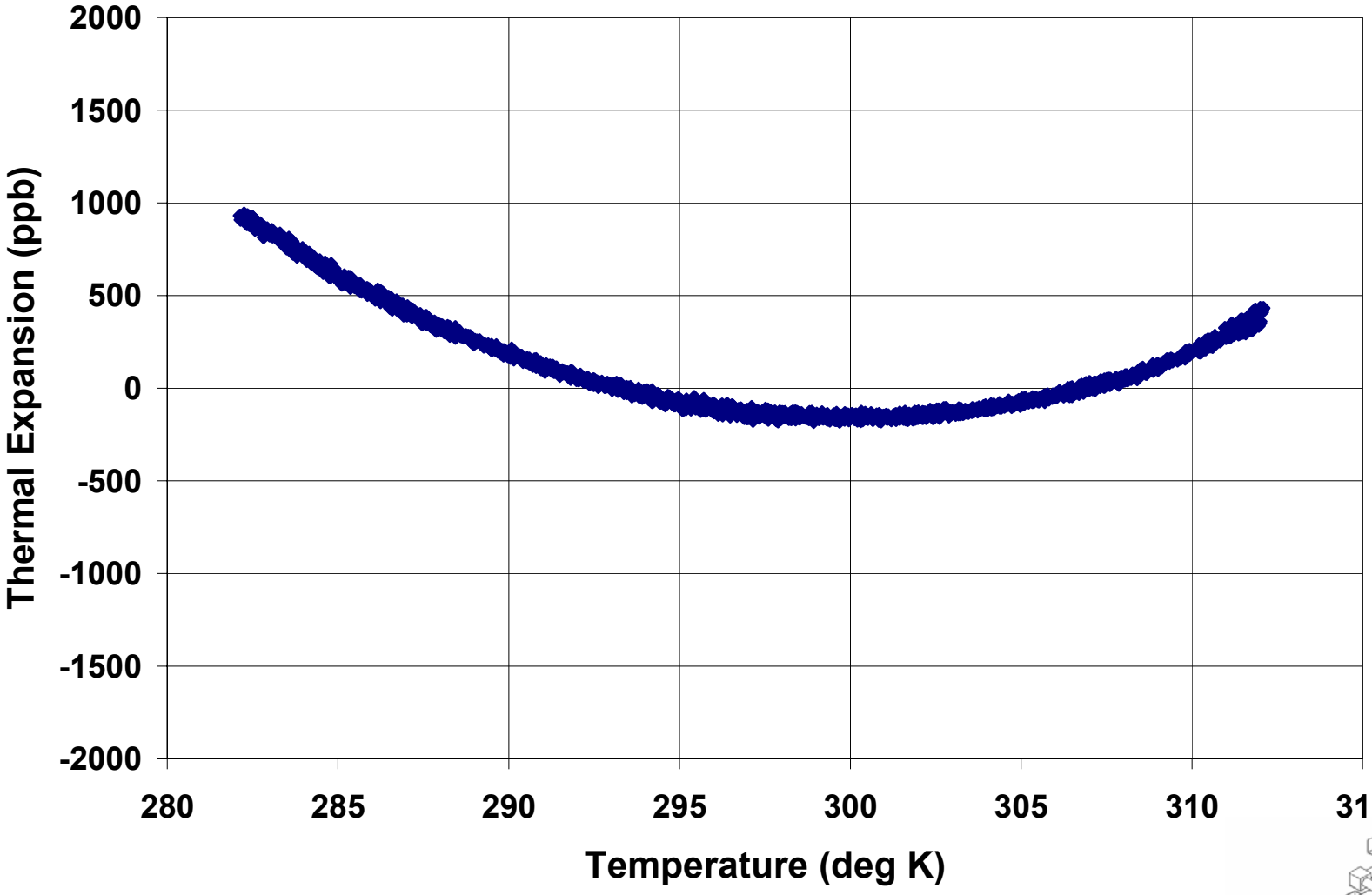
Thermal Expansion of ATK Composite Tube
(Note: Scale is Parts Per Billion)



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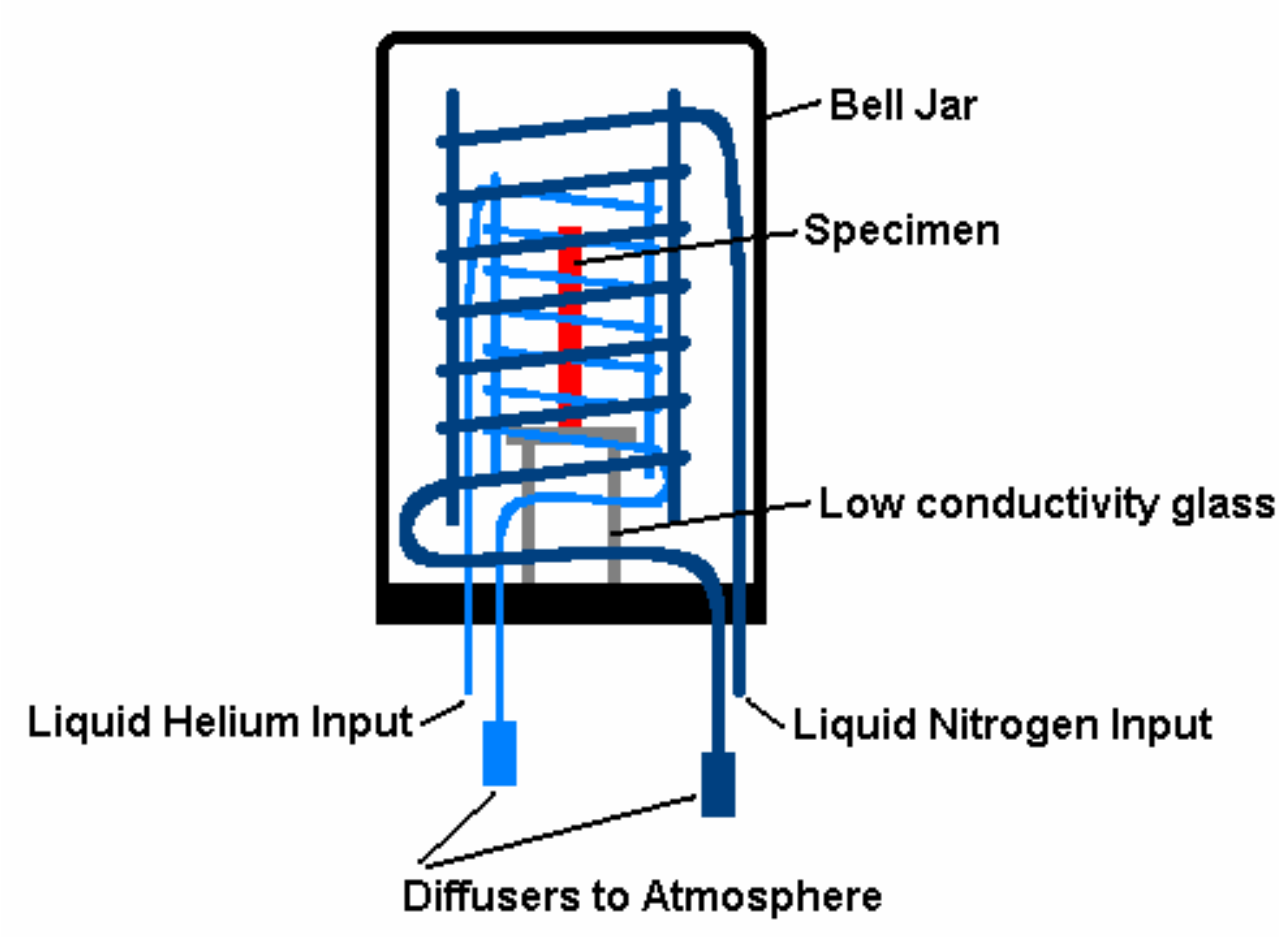
Cryogenic Chamber



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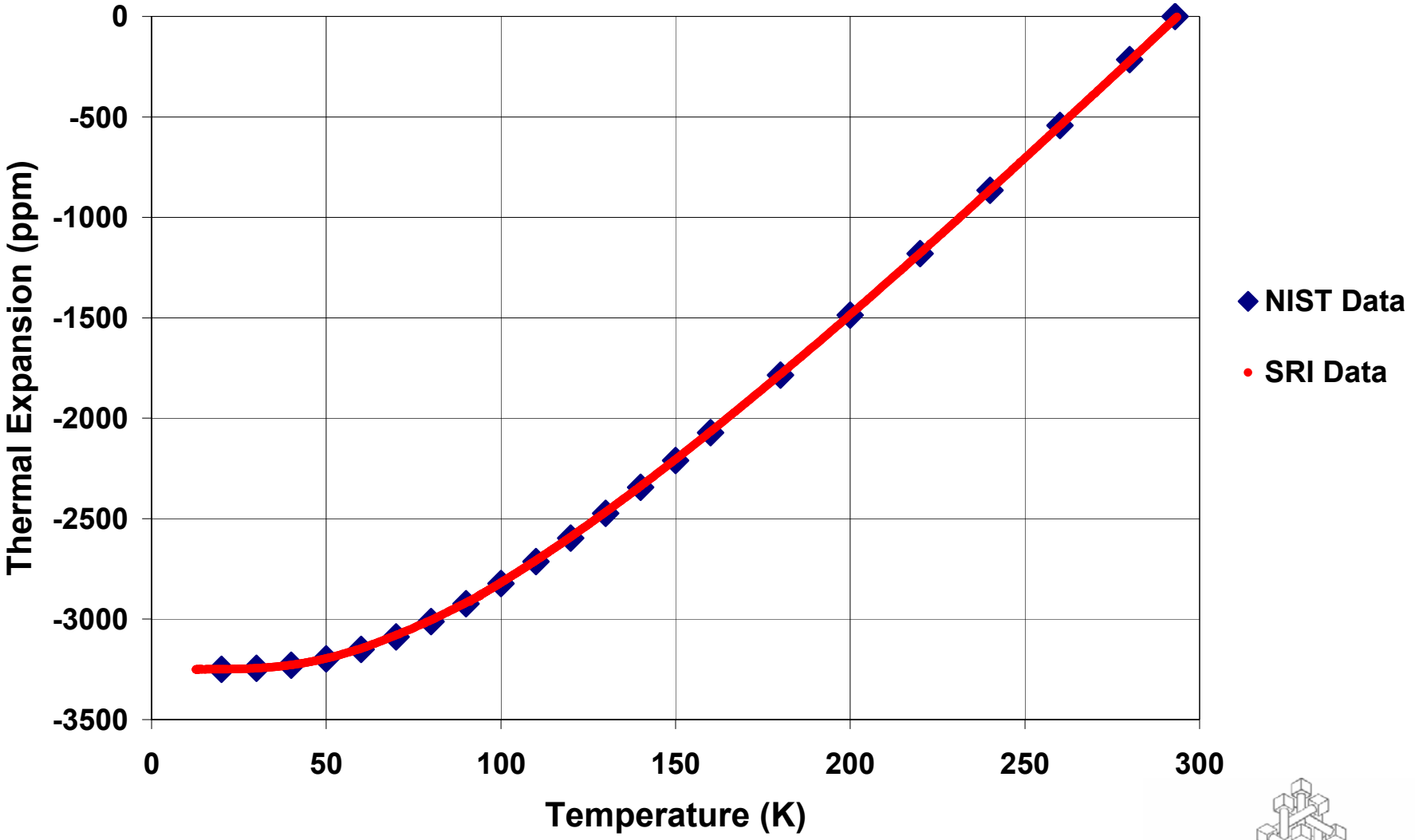
Southern Research Measured Thermal Expansion of NIST Copper SRM 736 Compared to Nist Data



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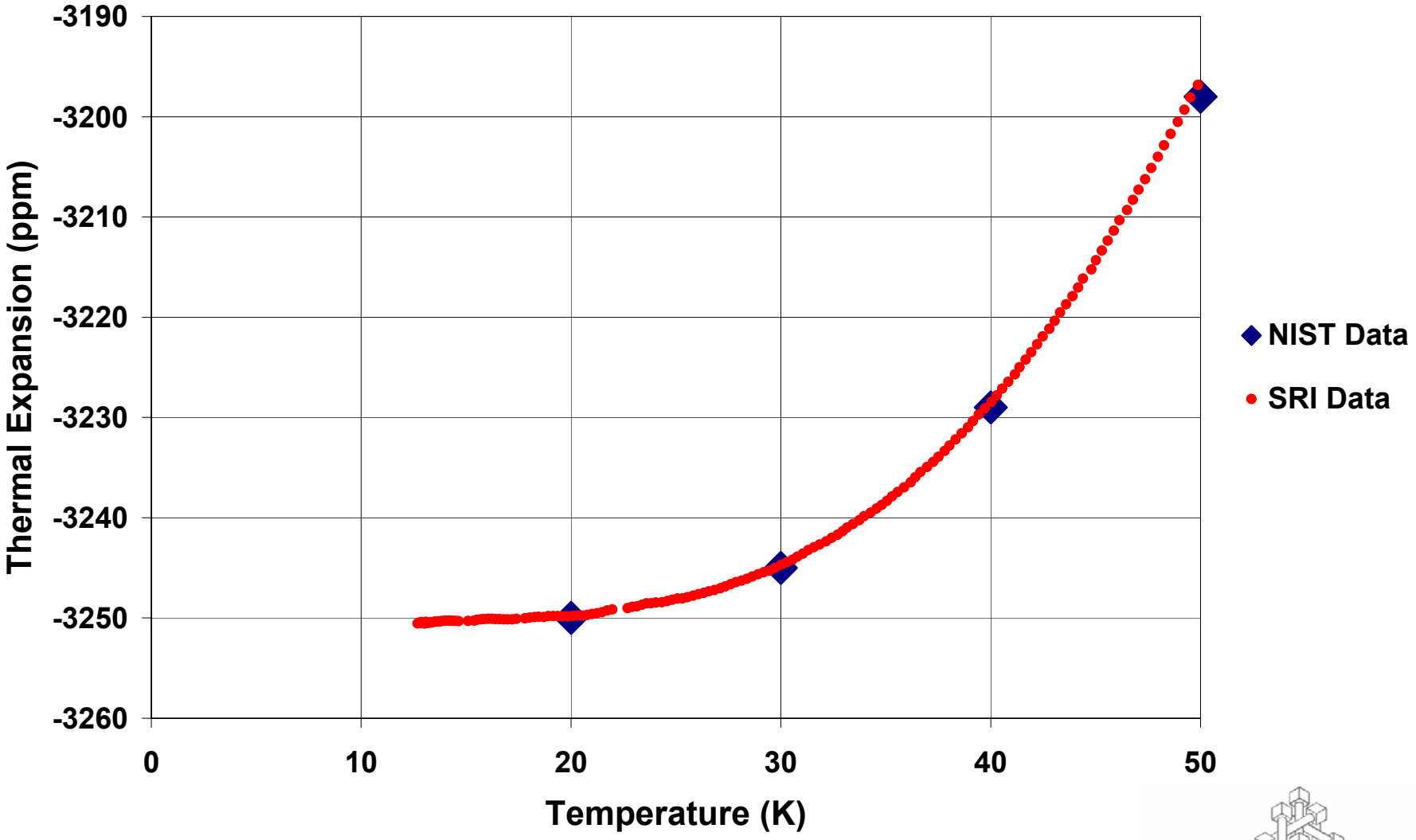
NIST Copper SRM 736 Thermal Expansion Below 50 K



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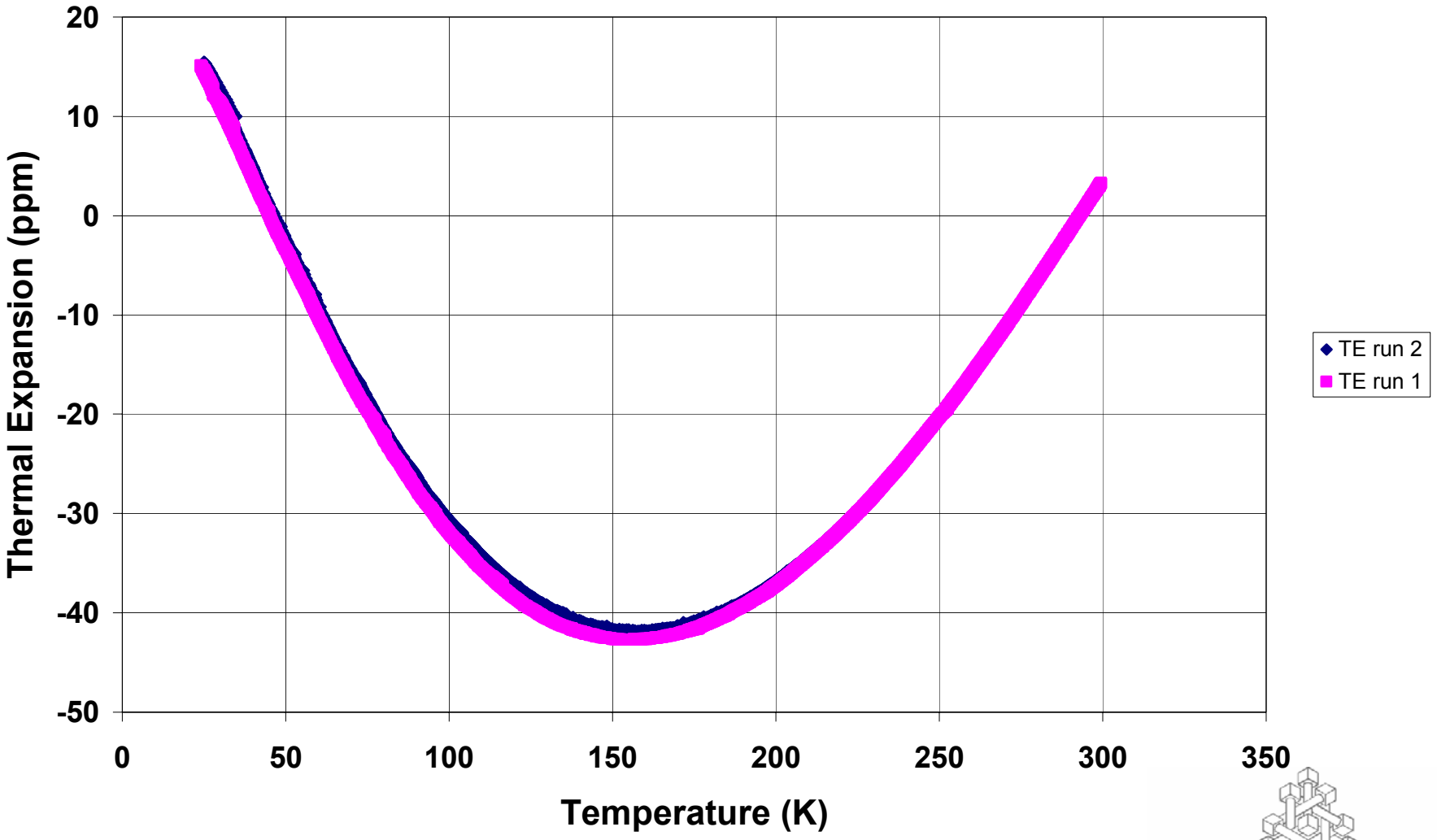
Replicate Runs of Fused Silica Specimen



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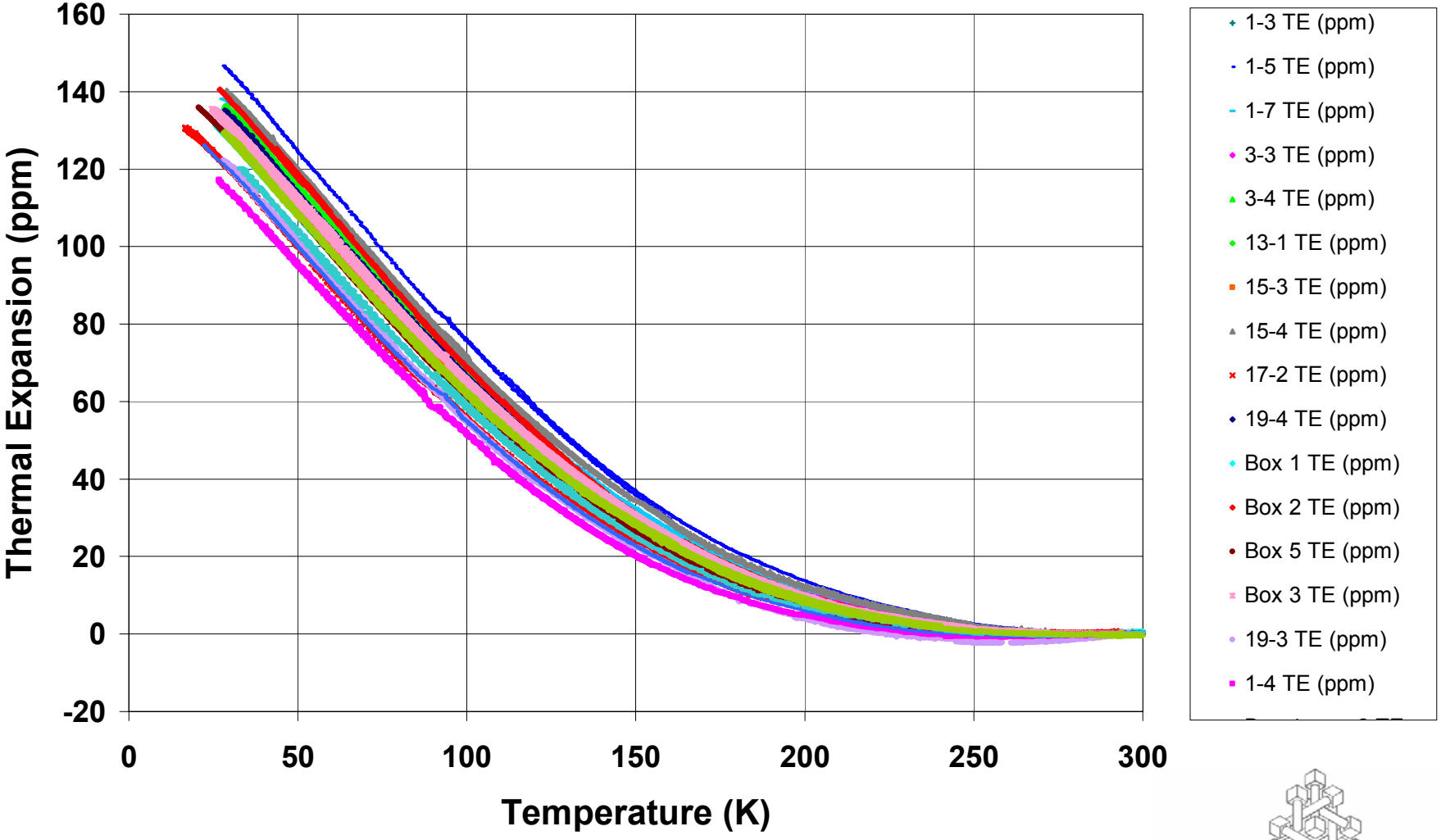
Summary of ULE Thermal Expansion



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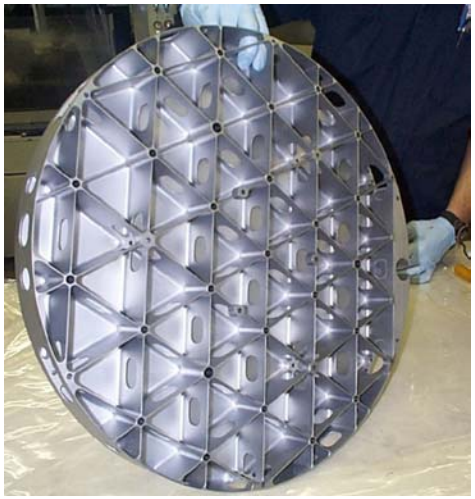
Background of Southern Research Testing for SOMTC MSFC

The thermal expansion testing of beryllium at Southern Research was undertaken to investigate a possible source of anomalous behavior observed during the cryogenic optical testing of the Subscale Beryllium Mirror Demonstrator (SBMD). The SBMD was developed by Ball Aerospace & Technologies Corp. to support their work with the James Webb Space Telescope (JWST). Since the JWST will require lightweight, deployable optics operating at cryogenic temperatures the SBMD sought to demonstrate the feasibility of beryllium as a candidate material for the mirrors.



SBMD mirror during fabrication

SBMD ready for testing

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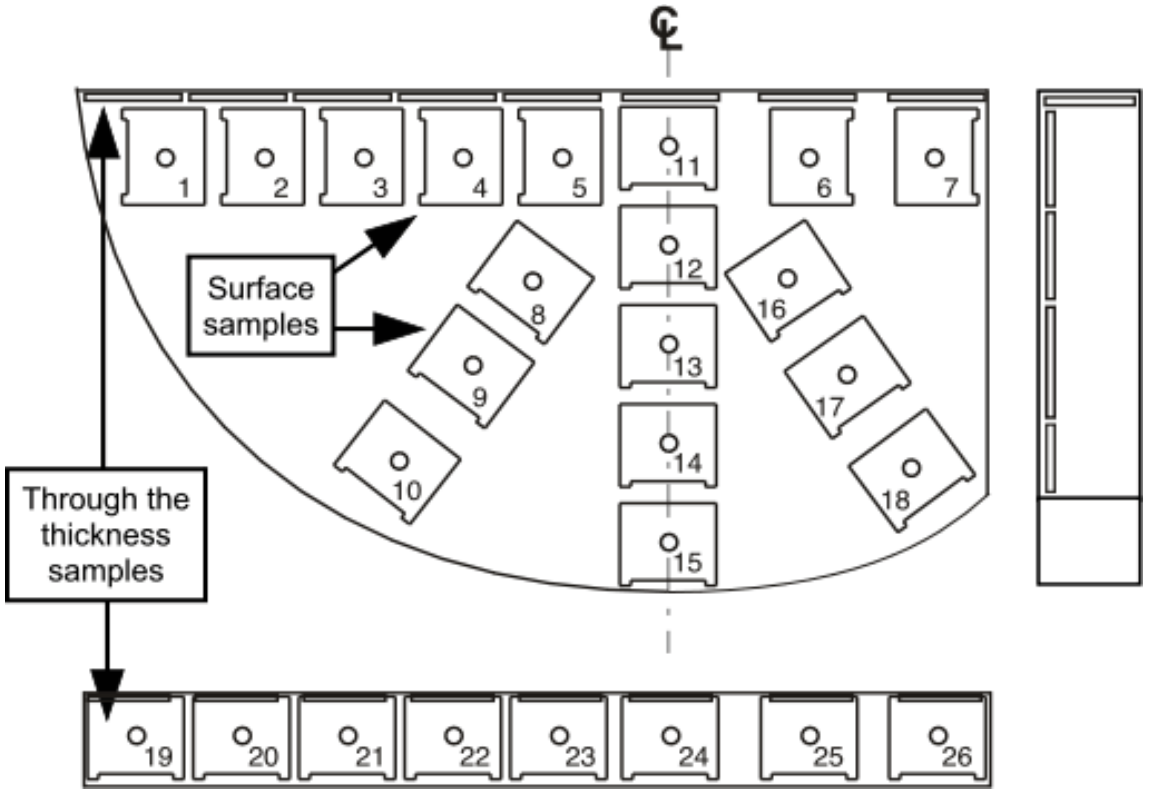
Beryllium Sample Test Plan



Layout of thermal expansion samples in beryllium billet remnant

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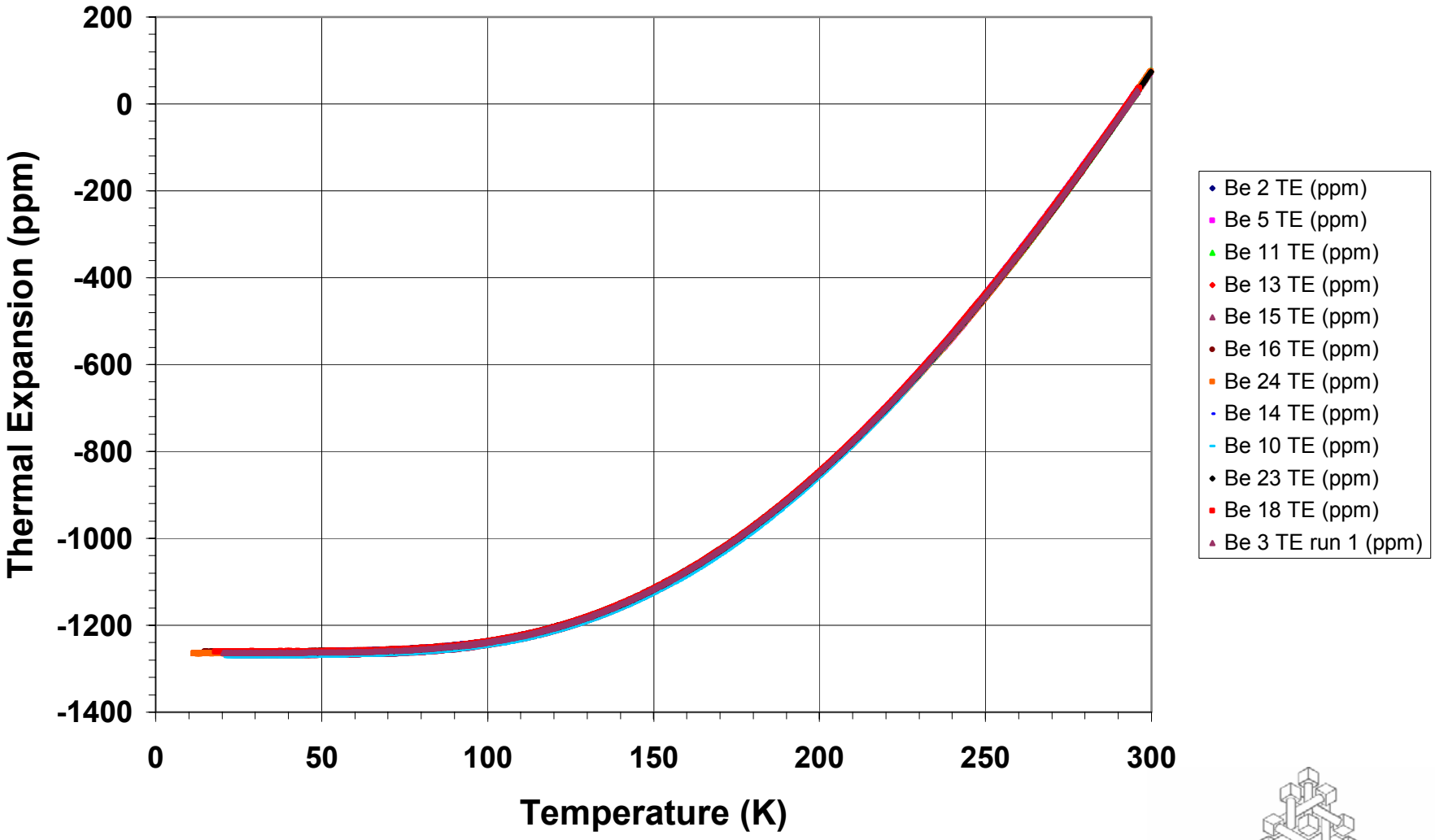
Summary of Beryllium Thermal Expansion



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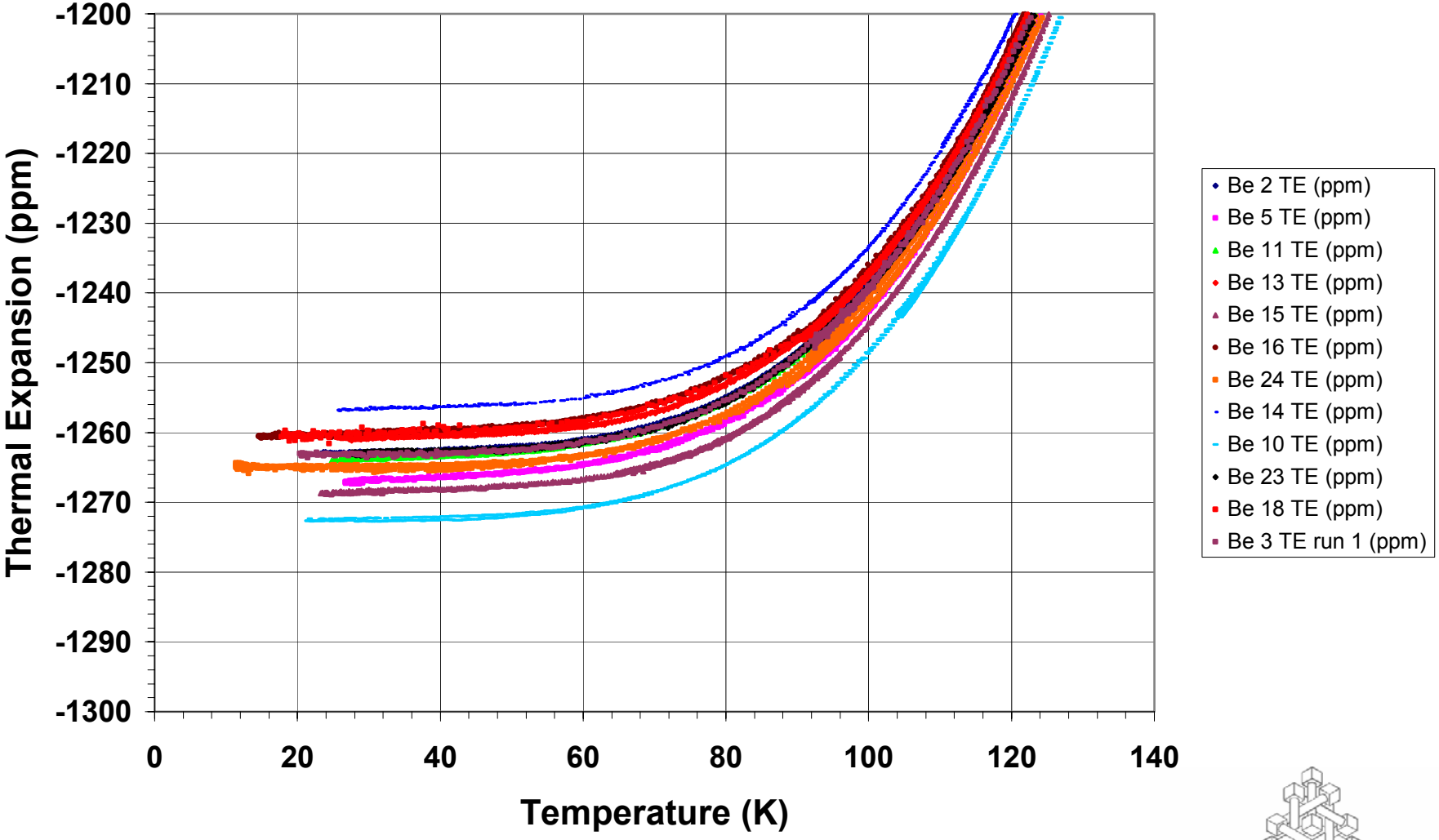
Summary of Beryllium Thermal Expansion



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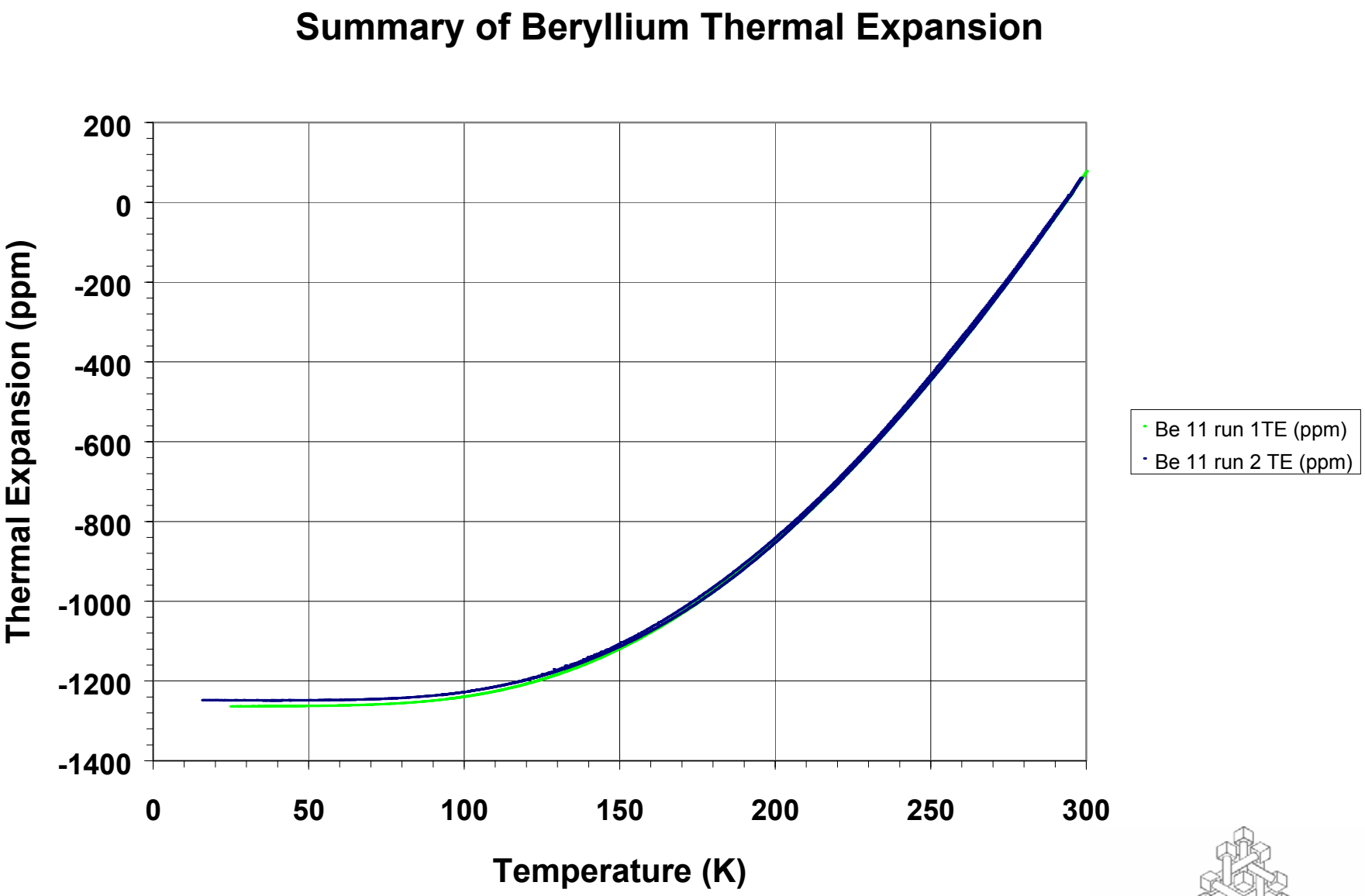
Overlay of 2 Runs for Be 11



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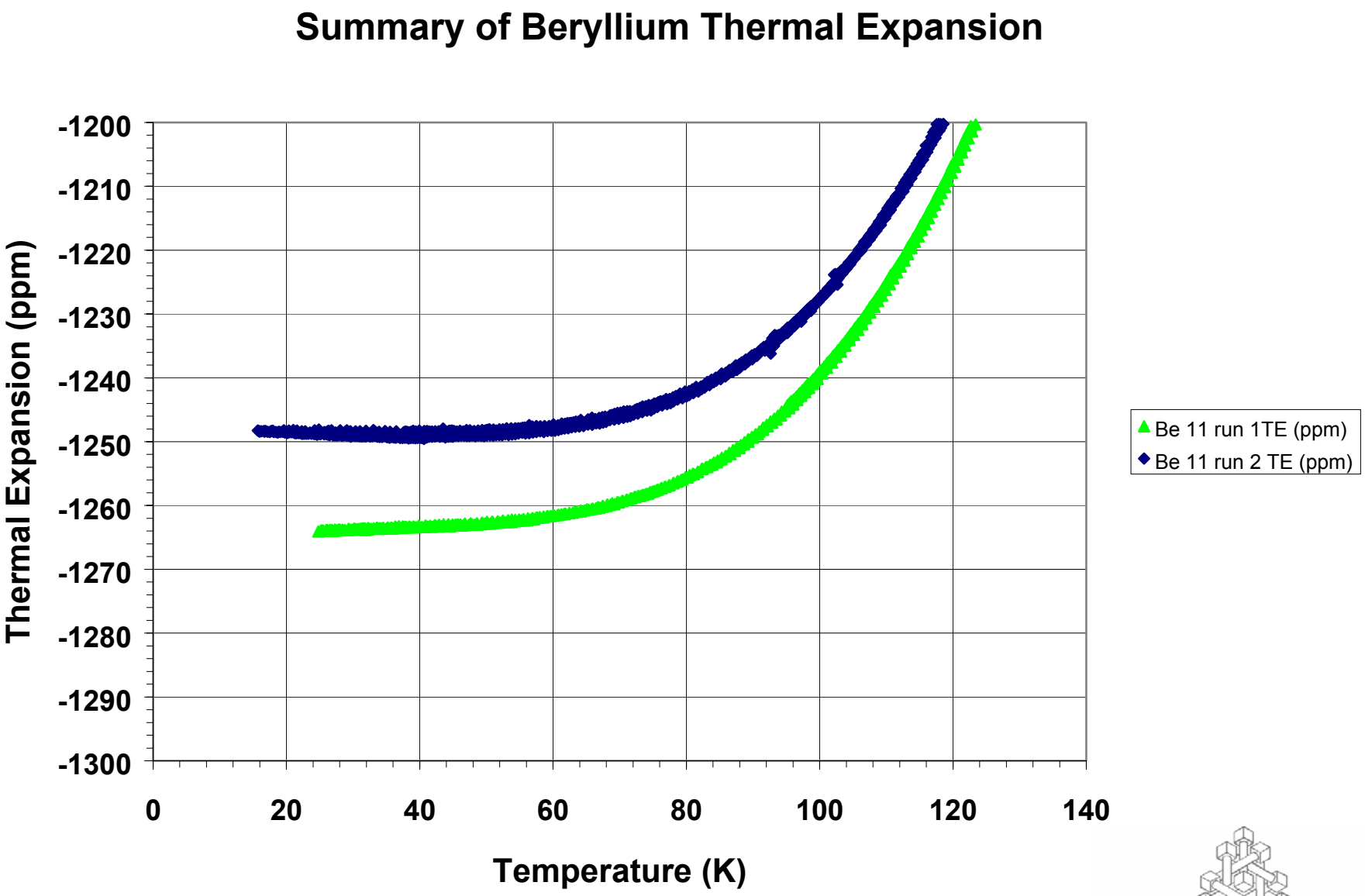
Overlay 2 Runs for Be 11 – Cold End



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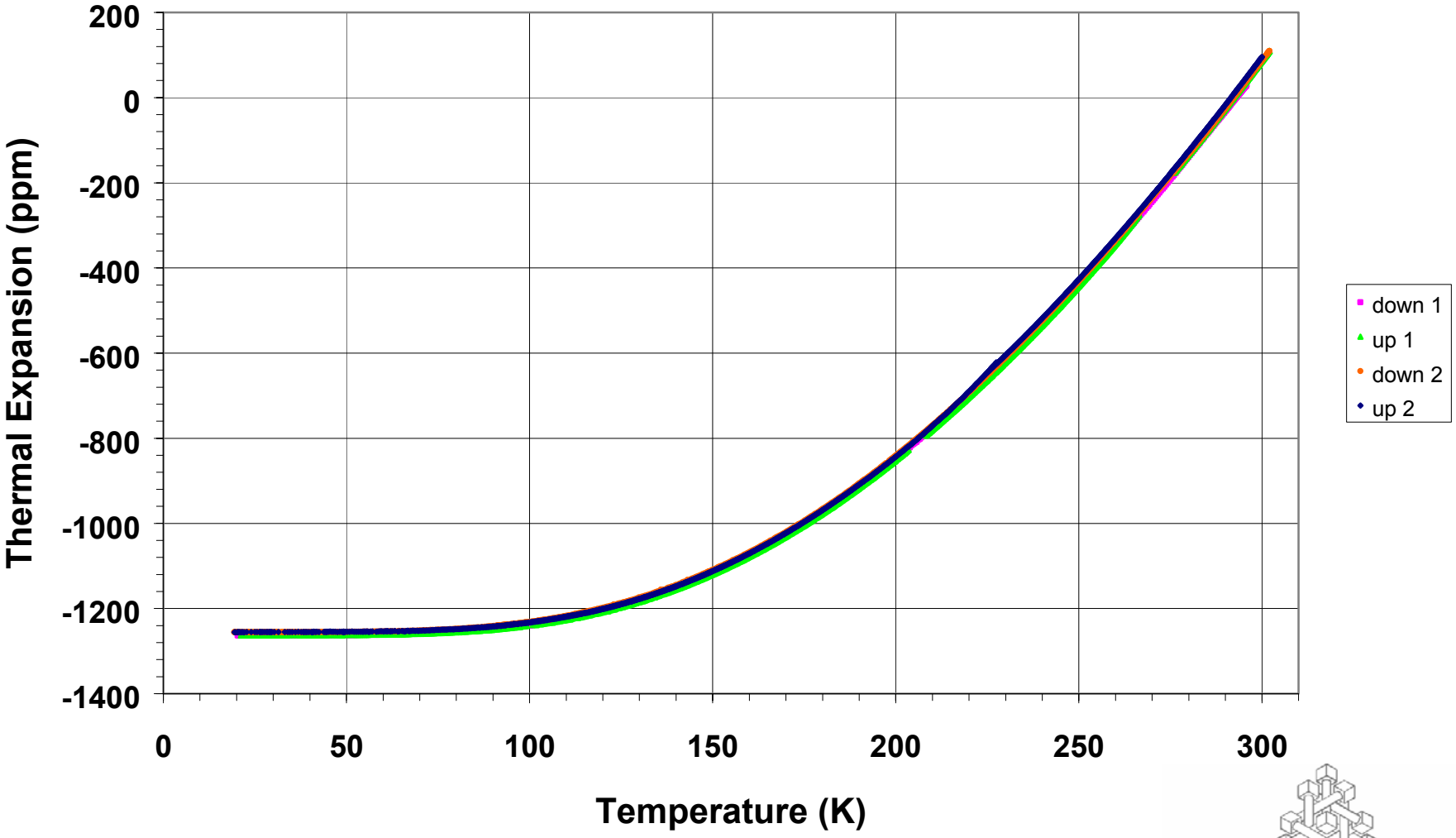
Thermal Expansion of Be 3 (2 continuous runs)



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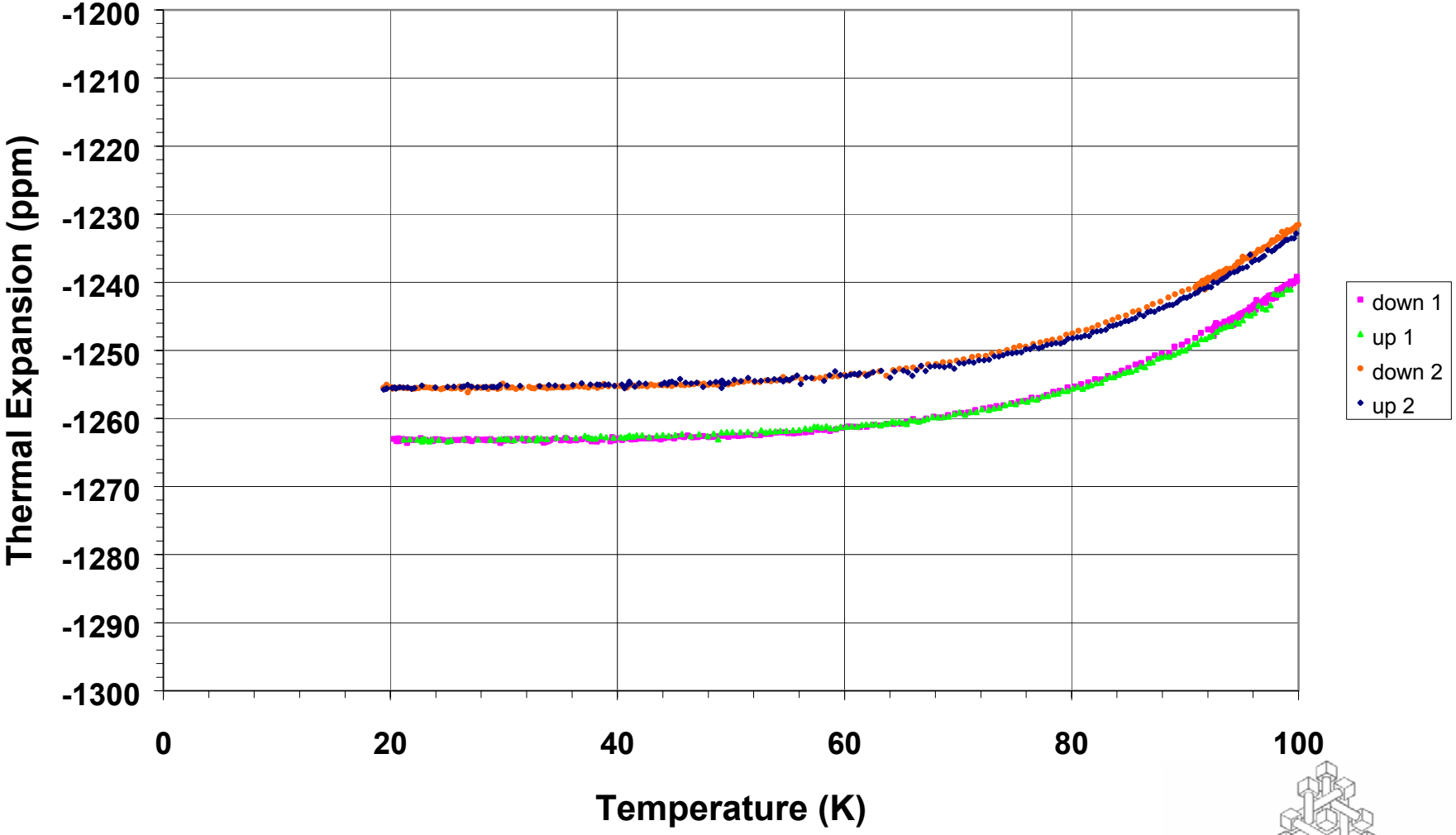
Thermal Expansion of Be 3 (2 continuous runs)



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Summary

- A hearty method for high accuracy thermal expansion has been developed
  - Error analysis and empirical data indicate accuracy in the low part-per-billion range for most test conditions
  - A large range of specimen size and type can be accommodated
- Concerns
  - Test verification has been to large magnitude (Cu) NIST standard
  - Lack of repeatability has been traced to specimen thermal gradients
- Future Plans
  - Plans are in place to compare results with independent sources
  - Liquid cryogen is currently being replaced with 4 K cryocooler (this will improve thermal control, reduce gradients, lower cost and open up additional test capability such as cryogenic micro-yield and actuator verification)

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